Synopsis on

DESIGNING PROTOCOLS TO SUPPORT QUALITY OF SERVICE ISSUES IN WIRELESS SENSOR NETWORKS

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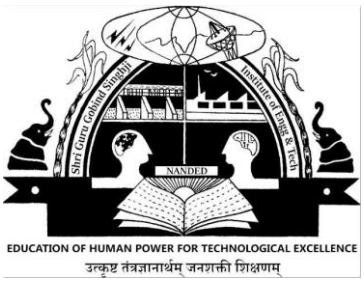

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1. Introduction and Motivation

Wireless sensor network (WSN) consists of spatially distributed autonomous sensors nodes to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants. Basically, each sensor node comprises sensing, processing, transmission, mobilizer, position finding system, and power units. These nodes collects and transmits the information. WSN have wide range of applications in military, environmental monitoring, healthcare, habitat monitoring and surveillance. But limited memory, low power and limited processing nature of WSN impose several issues also. Energy conservation is an important issue to be considered. WSN are also used in real time applications, the transmission of imaging and video data requires careful handling in order to ensure that end-to-end delay is within the acceptable range and that the variation in such delays is acceptable so reliability and timeliness becomes important Quality of Service (QoS) parameters in real time applications [1].

QoS has become very important topic in WSN research. Different QoS parameters were used in traditional networks such as packet loss, delay, jitter, bandwidth etc. However, the QoS requirements in WSNs such as data accuracy, aggregation delay, coverage, fault tolerance and network lifetime etc. are application specific and they are different from the traditional end-to-end QoS requirements due to the difference in application domains and network properties [2]. The QoS models used in internet and adhoc networks like Differentiated Services (DiffServ) and Integrated Services (IntServ) cannot be used in WSN due to their different nature. QoS mechanisms used to support QoS in wired data networks and wireless networks cannot be directly applied to wireless sensor networks because of the bandwidth constraint and dynamic network topology. Wireless sensor networks have certain unique characteristics that pose several challenges in provisioning QoS. Some of the characteristics are dynamically varying network topology, lack of precise state information, lack of a central controller, error prone shared radio channel, limited resource availability, hidden terminal problem, and insecure medium [3]. In this context, we are required to implement complex QoS functionality with limited available resources in a highly dynamic environment.

QoS provisioning has been researched extensively for traditional wired and wireless networks. The QoS in WSN however, has a different perspective. The number of nodes, the nodes'

capabilities, and deployment strategy, play a significant role in the WSN's QoS capacities. Most of the current QoS provisioning methods in WSN are inadequate from the users' point of view, since they are adapted in efficient mechanisms like end to- end path discovery and recovery mechanisms, resource reservations, static routing and so on. Moreover, WSN deals with resources that are dynamically changing, including energy, bandwidth, node density and connectivity. At present, more and more new classes of applications are pouring in and they also deal with multiple classes of traffic patterns like periodic, discrete event and impulse wave. Most of the new classes of applications require better QoS support. It is a very challenging task to provide good solutions using the existing state of the art. In this situation it is inevitable and optimum, to design new QoS providing protocols to meet real-world expectations.

2. Literature Survey

WSNs have two main approaches for QoS provisioning: classic layered approach and cross-layer approach. Layered approach achieves QoS provisioning with protocols that operate only in one individual layer of the WSN communication protocol stack, while cross-layer approach provides the desired QoS through the simultaneous interaction of multiple layers in WSN. QoS provisioning in the MAC, network and transport layer is surveyed below. Since the MAC layer is the bottom layer, it has a huge impact on QoS provisioning in the upper layers. Therefore, it must guarantee one or more performance metrics to upper layers. Protocols in each layer are isolated and do not alter the protocols in upper or lower layers.

MAC Layer

Since the MAC layer is the bottom software layer, performance of all upper layers are depending on the MAC layer components and performance. QoS support in the network or transport layers cannot be provided without the assumption of a MAC protocol which solves the problems of medium sharing and supports reliable communication [4]. Therefore, QoS provisioning in MAC layer is of significant importance for overall QoS in WSN. QoS metrics that can be fulfilled at the MAC layer are [4]: minimizing medium access delay, minimizing collisions, maximizing reliability, minimizing energy consumption, Minimizing interference and maximizing concurrency (parallel transmissions),Maximizing adaptation to changes.

QoS mechanisms that can be used at the MAC layer are the following [4]: **Adaptation and learning:** Adapts operation parameters of the sensor nodes to the current network condition in order to accommodate traffic load in a more efficient way. Over time, learning algorithms could predict network changing and take necessary adaptive operations. **Error control:** Reduces consumption, whilst providing reliable and fast delivery of the sensor data. It can be implemented in each layer of the communication protocol stack. **Data suppression and aggregation:** Reduces traffic load of the network and consequently minimizes radio communication, preserves energy and increases bandwidth. It can also be implemented in each layer of the communication protocol stack. **Power control:** Adjusts transmission power of the sensor nodes to the minimum power required for successful transmission. It is implemented in MAC layer as a joint physical-MAC layer solution. **Clustering:** Simplifies the synchronization and coordination by grouping set of neighboring sensor nodes. Consequently, it lowers energy consumption and improves reliability. Service differentiation: Prioritizes network traffic based on several criteria, and then forms several traffic classes. Different QoS levels are provided to different traffic classes.

In [5], authors reviewed several aspects on QoS provisioning at MAC layer. They conclude that an approach based on quantitative modeling of energy-efficiency vs. delay trade-off, based on information theoretic and wireless communications principles, is promising. However, multimedia, critical and real-time WSNs should not have delay-constrained communication. Therefore, it could be difficult to found the right balance between delays and energy consumption. In [6], authors developed a novel Scalable QoS MAC (SQ-MAC) protocol that guarantees QoS to multimedia traffic, still images and scalar sensor data in multi-hop WSN.

In addition, novel and interesting QoS aware MAC protocols can be found in [7-9]. In [7], authors proposed novel MAC protocol for supporting mobile clusters in WSNs. Unlike previous protocols, Mobile Cluster MAC (MCMAC) protocol supports moving clusters like Wireless Body Area Network (WBAN) in which nodes are mobile and several nodes move together at once.. RoMAC [8] is localized QoS-aware MAC protocol that can be used in dynamic and challenging environments. Similar to MCMAC protocol, described in [14], the transmission schedule of each node is determined by its frame set and its transmittable slot in each frame. Consequently, RoMAC achieves resilience to topology change and is traffic adaptive in dynamic environments. Furthermore, it provides persistent QoS support in terms of timeless, packet jitter and fairness.

Priority-based QoS MAC (PQMAC) protocol [9] divides data into classes according scenario, application, and transmission type every class has its own priority level and high-priority data are placed into a high-priority queue and low-priority data are placed into a low-priority queue. Therefore, high-priority data have the opportunity to be sent during any listen time.

Network Layer

Routing protocols are implemented primarily in the network layer and they are in charge of discovering and maintaining the routes in the network. Most of the routing protocols designed for WSNs consider energy efficiency as the main objective, with the assumption that data does not have stringent QoS requirements [10]. They can be classified as data-centric, hierarchical, location-based or network-flow protocols. In data-centric protocols, queries are posed for specific data and routing is performed using the knowledge that is aggregate or meta-data. Hierarchical protocols minimize energy consumption by dividing nodes into clusters. Location- based protocols take advantage of the location information to make routing techniques more efficient. In network flow protocols, route step is modeled and solved as a network- flow problem. QoS metrics that can be fulfilled at the network layer are: Minimizing path latency/delay, Maximizing routing reliability, Minimizing energy consumption, Minimizing congestion probability, providing effective sample rate.

In [11], authors developed novel QoS localized routing protocol, which is designed using a modular approach, based on differentiation routing. It uses traffic differentiation while considering three different QoS parameters: (i) Energy efficiency (including both residual energy and the required i) transmission power); (ii) Reliability; and (iii) Latency.

SPEED [12] is a well-known geographic routing protocol which allows real-time communications in WSN. Geographic routing protocols try to estimate the end-to-end delay by computing the distance between the source and the sink. This distance is estimated using the location information obtained through localization techniques. MMSPEED [13] is an extension of SPEED that adds a differentiated priority packet delivery mechanism and improved reliability using multipath forwarding. MMSPEED provides multiple QoS levels in the timeliness domain by using different delivery speeds (different relay nodes), while different reliability requirements are supported by probabilistic multipath forwarding. The number of delivery paths is based on the required end-to-end reaching probability.

In addition, novel and interesting QoS aware routing protocols can be found in [14-16]. QoSNET [14] is a multipath routing protocol designed for large scale heterogeneous WSNs. It is based on separation of the nodes into two sub networks. The first is used for signaling operations and routing decisions, and the second is used for routing operations. Simulation results show that QoSNET can meet hard QoS constraints and extend network lifetime. EQSR [15] is multipath routing protocol that performs routes discovery using multiple criteria such as energy remaining, remaining buffer size and signal-to-noise ratio. It increases throughout and reduces the end-to-end delay by distributing the traffic amongst the available paths, maximizes the network lifetime through balancing energy consumption across multiple nodes and employs a queuing model to handle both real-time and non-real-time traffic. In [16], a biologically-inspired algorithm was used for QoS support in Wireless Multimedia Sensor Networks (WMSNs). AntSensNet routing protocol is based on traditional ant-based algorithm and it meets application QoS requirements and improves network performance in terms of delivery ratio, end-to-end delay and routing overhead.

Transport Layer

Transport protocols run over the network layer protocols. They are designed to control source transmissions, and to provide reliable message delivery and congestion control. QoS metrics that can be fulfilled at the transport layer are: Maximizing end-to-end reliability, Bandwidth/throughput fairness, Minimizing congestion probability, Minimizing energy consumption. QoS mechanisms that can be used at the transport layer are: Loss recovery, Congestion control, Flow control.

Congestion is one of the major issues which adversely affect all the QOS parameters. Congestion must be avoided in order to improve QoS in a wireless sensor network in terms of link utilization, throughput and error and delay minimization. Congestion control is very important to improve QoS in WSN.

Ali Ghaffari classifies congestion control methods into four categories i.e. traffic control protocols, resource control protocols, queue assisted protocols and priority-aware protocols [17]. In traffic control congestion is mitigated by means of reducing the number of packets injected into WSNs. Traffic control techniques are categorized according to additive increase multiplicative decrease or a rate-based method. Resource control protocol mitigates congestion by creating alternative paths to the base stations during congestion. Priority based protocols assigns priorities

to sensor nodes to ensure that certain nodes receive priority-dependent throughput. The queue-assisted protocols mainly focus on the queue length of the nodes and use a simple rate adjustment technique such as Additive Increase Multipartite Decrease (AIMD) to keep the queue length of nodes as low as possible.

Syed Afsar Shah et al., 2017 categorized congestion control into centralized with partial congestion control and distributed with dedicated congestion control [18]. In the centralized congestion control schemes, all the actions related to avoid or control congestion are undertaken by the sink node/base station. The different protocols employed for congestion control in wireless sensor networks, basically deal with three core functions- controlling the congestion, avoiding the congestion and providing for reliable data transportation. Following are some examples of protocols which deals with congestion control.

Best congestion control technique is based on various performance metrics such as energy efficiency, throughput, average delay and packet dropping. Depending on data delivery mechanism, all applications of WSNs can be categorized into event driven, continuous, query-driven, and hybrid. Therefore, the type of application and location of occurrence of congestion, are considered distinguishing features among various congestion control protocols. Applying the same congestion control technique to all applications and all congestion locations is, by no mean appropriate and will consequently lead to performance degradation [19]

In addition, several transport protocols with QoS support can be found in [20-22]. Wireless Modular Transport Protocol (WMTP) [20] uses a modular architecture and provides different features, namely congestion control, fairness, reliability, optionally integrated service-discovery and QoS. However, only the fairness feature was evaluated through a series of tests. Experimental results show that WMTP protocol ensures throughout fairness and minimizes congestion probability with minimal energy cost. POWER-SPEED [21] achieves an energy-efficient data transport for delay sensitive event reporting in real-time WSANs. It avoids the overhead of control packets by selecting the next-hop neighbor based on the downstream path quality and the latency bound requirement of packets. Therefore, it maintains QoS requirement in timeliness domain. In [22], authors presented a protocol that uses a rate control mechanism to adjust the transmission rate of each sensor node based on the congestion degree in the network. It supports QoS by controlling congestion and providing reliability in packet delivery.

3. Problem Statement and Objectives

This research is aimed towards designing protocols to support quality of service issues in Wireless Sensor networks. Objectives are as follows.

(a) To Study various QoS issues in wireless sensor networks.

(b) To Design protocols which will support QoS issues at different layers of WSN.

(c) Design and development of congestion control protocol which will support QoS issues in WSN.

4. Plan of Research Work

Phase	**Work To Be Carried Out**
I	- Literature Survey, Course Work - Formulation of Problem Definition, Objectives and Feasibility Study.
II	- Survey paper publication - Design and development of congestion control protocol
III	- Testing and Performance Evaluation. - Publications in reputed journals and Thesis Writing

5. Impact on Society

The wireless networking capability of the sensor enabled nodes have resulted in various interesting applications ranging from surveillance, smart homes, precision agriculture, disaster detection, military and traffic control to vehicular and supply chain management applications. The improvement of WSN has been resulting in various applications which are making life easier and comfortable. Similarly, a variety of applications of WSN can be seen in medical healthcare. WSN has put an enormous impact on medical healthcare in terms of reducing the patient's risks of severity in emergency situations and providing them with a friendly environment at homes.

6. References

1. Sumathi,R. and Srinivas,M.G. (2012) . A Survey of QoS Based Routing Protocols for Wireless Sensor Networks, Vol.8, No.4, December 2012.

2. Bhuyan,B., Kumar,H., Sarma, D., Sarma,N. Quality of Service (QoS) Provisions in Wireless Sensor Networks and Related Challenges. Wireless Sensor Network, 861-868, 2010

3. Archana Bharathidasan and Vijay Anand Sai Ponduru, 'SENSOR NETWORKS: An Overview', Survey paper, IEEE Infocom, pp. 54-63, 2004
4. Yigitel MA, Incel OD, Ersoy C. QoS-aware MAC protocols for wireless sensor networks: A survey. Comput Net 2011;
5. Zogovic N, Dimic G, Bajic D. Wireless Sensor Networks: QoS Provisioning at MAC and Physical Layers. In 17th Telecommunications Forum TELFOR. Serbia, Belgrade, November 24-26, 2009.
6. On J, Jeon H, Lee J. A scalable MAC protocol supporting simple multimedia traffic QoS in WSNs. Int J Distrib Sensor Net 2011;
7. Nabi M, Blagojevic M, Geilen M, Basten T, Hendriks T. MCMAC: An Optimized Medium Access Control Protocol for Mobile Clusters in Wireless Sensor Networks. Proceedings of the 7th Annual IEEE Communications Society Conference on Sensor Mesh and Ad Hoc Communications and Networks. Boston, USA, June 21-25, 2010.
8. Huang R, Song WZ, Xu M, Shirazi B. Localized QoS-aware Media Access Control in High-fidelity Data Center Sensing Networks. Proceedings of the International Conference on Green Computing. Chicago, USA, August 15-18, 2010.
9. Kim H, Min SG. Priority-based QoS MAC Protocol for Wireless Sensor Networks. Proceedings of the IEEE International Symposium on Parallel & Distributed Processing. Rome, Italy, May 23- 29, 2009.
10. Ehsan S, Hamdaoui B. A survey on energy-efficient routing techniques with QoS assurances for wireless multimedia sensor networks. IEEE Commun Surv Tutor 2011;
11. Djenouri D, Balasingham I. Traffic-differentiation-based modular QoS localized routing for wireless sensor networks. IEEE Trans Mobile Comput 2011;
12. He T, Stankovic JA, Lu C, Abdelzaher TF. A Spatiotemporal Communication Protocol for Wireless Sensor Networks. IEEE Trans Parallel Distrib Syst 2005;
13. Felemban E, Lee CG, Ekici E. MMSPEED: multipath multi-speed protocol for QoS guarantee of reliability and timeliness in wireless sensor networks. IEEE Trans Mobile Comput 2006;

14. Houngbadji T, Pierre S. QoSNET: An Integrated QoS Network for Routing Protocols in Large Scale Wireless Sensor Networks. Comput Commun 2010;
15. Ben-Othman J, Yahya B. Energy efficient and QoS based routing protocol for wireless sensor networks. J Parallel Distrib Comput 2010;
16. Cobo L, Quintero A, Pierre S. Ant-based routing for wireless multimedia sensor networks using multiple QoS metrics. Comput Net 2010;
17. Ali Ghaffari, Congestion control mechanisms in wireless sensor networks: A survey, Journal of Network and Computer Applications 52 101–115, 2015.
18. Syed Afsar Shah, Babar Nazir , Imran Ali Khan ,"Congestion control algorithms in wireless sensor networks: Trends and opportunities", Journal of King Saud University – Computer and Information Sciences 29, 236–245, 2017.
19. Jan, Mian Ahmad, et al. "A Comprehensive Analysis of Congestion Control Protocols in Wireless Sensor Networks." Mobile Networks and Applications, doi: 10.1007/s11036-018-1018-y, 2018
20. Pedrosa LD, Rocha RM. WMTP - A Modular WSN Transport Protocol: The Fairness Module. Proceedings of the New Technologies, Mobility and Security. Tangier, Marocco, November 5-7, 2008.
21. Zhou Y, Ngai ECH, Lyu, MR, Liu J. POWER-SPEED: A Power- Controlled Real-Time Data Transport Protocol for Wireless Sensor- Actuator Networks. Proceedings of the IEEE Wireless Communications and Networking Conference, Hong Kong, March 11-15, 2007.
22. Yaghmaee MH, Adjeroh D. A Reliable Transport Protocol for Wireless Sensor Networks. Proceedings of the International Symposium on Telecommunications, Tehran, Iran, August 27-28, 2008.

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